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BARBERRY ERADICATION AND SOURCES OF BLACK STEM RUST IN COLORADO

By L. W. DURRELL and E. A. LUNGREN

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BARBERRY ERADICATION AND SOURCES OF BLACK STEM RUST IN COLORADO

By L. W. DURRELL and E. A. LUNGREN[1]

A study of the cereal rusts has shown that, tho there are several kinds, the black stem rust is the chief cause of damage. For many years this rust has caused repeated loss to the farmers of Colorado, the average yearly loss during the period 1916 to 1926 being estimated at $300,000.

There are three possible sources of black stem rust infection of cereals in Colorado. The rust may come from susceptible barberry bushes in early spring; it may overwinter on living wheat or wild grasses and spread rapidly in the spring; or it may migrate from neighboring states where there are barberries or where the winters are mild and the rust overwinters on living grains and grasses.

Of these three sources of black stem rust, the barberry is the most important because it gives the rust such an early start that, by the time the grain is heading, millions of rust spores have been discharged by the infected bushes and have spread to the grain fields.

In order to understand more clearly the rust situation in Colorado, it is proposed that this paper be devoted more particularly to the behavior of black stem rust, its migration into the state, the possibility of its overwintering on grains or wild grasses, and the part played by barberries. It also is proposed to give a report of barberry eradication in the state and its effect on rust control.

Barberry as a Source of Black Stem Rust in Colorado

Black stem rust is caused by a microscopic parasitic plant closely related to such organisms as bread mold and the green mold of decaying fruit. This fungus parasite[2] spends the greater part of its life on the wheat plant. Here it produces two kinds of spores or rust germs, namely, red (or summer) spores and black (winter) spores. These spores develop in pustules which, because of their color, give the disease its name. The winter spores germinate during spring and produce a crop of very small colorless spores (sporidia). These sporidia are carried by winds to the leaves of susceptible barberry bushes. Here they germinate and produce infecting threads which penetrate the tissues of the barberry leaves and feed upon their tissues. Later on, the development of this infection ends in the eruption of the leaf

[2]*Puccinia graminis tritici*

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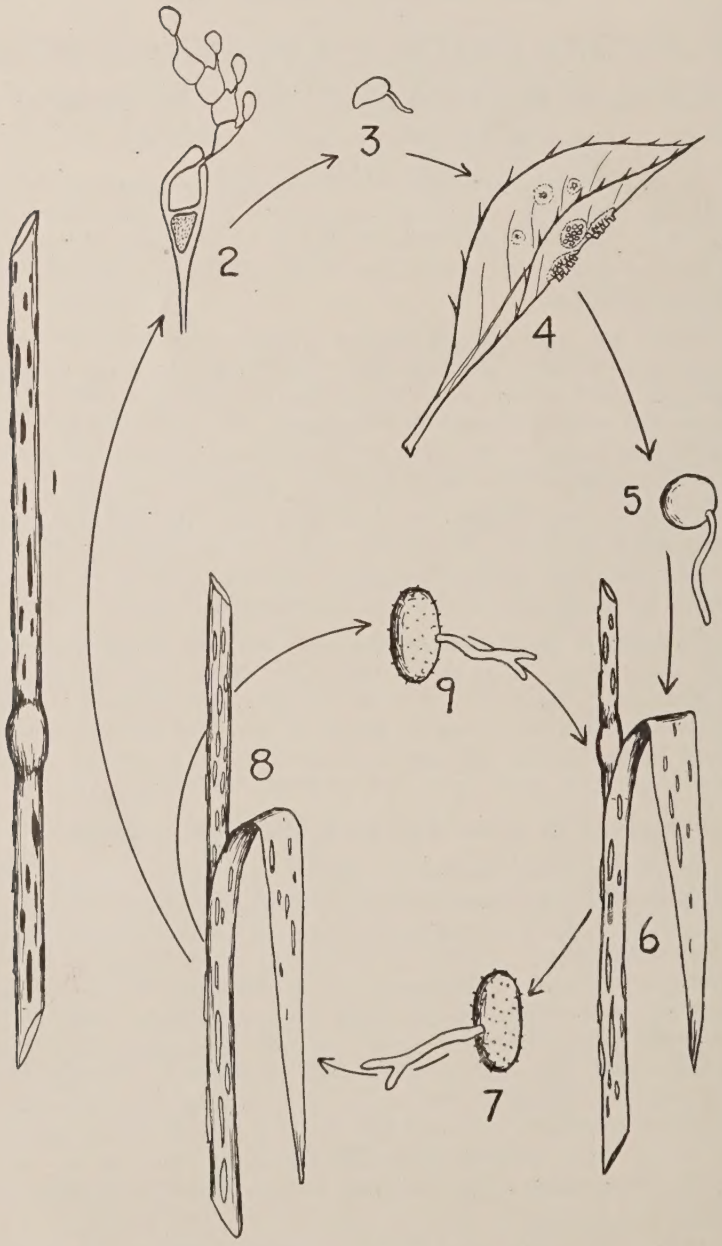

Fig. 1.—Life History of Black Stem Rust.

Fig. 2.—The common barberry bush (Berberis vulgaris), a breeder and distributor of stem rust.

surface into groups of small cluster cups. These cluster cups contain thousands upon thousands of yellow or cluster-cup spores. These spores are forcibly discharged from their cups and, if carried to growing wheat or related grasses, are almost sure to cause an outbreak of stem rust on these hosts. This, the "red rust" stage, is recognized by the appearance of brick-red, open pustules which con-

Fig. 1.—1—Wheat straw showing black-rust pustules. 2—A winter spore from a black-rust pustule producing secondary spores in spring. 3—A secondary spore. Spores of this kind germinate and cause rust infection of the barberry. 4—A barberry leaf infected with rust. 5—A rust spore from the barberry leaf. Spores of this kind cause black stem rust in growing grain. 6—Red-rust stage of black stem rust on grain traceable to infected barberry. 7—A red-rust spore. Spores of this kind may cause a further spread of rust to growing grain. 8—Red rust on grain spread from rust on other grain. 9—Red-rust spore from secondary spread. When the grain ripens, the black rust (winter) spores develop and the red (summer) spores are no longer produced.

tain thousands of red or summer spores. These may be blown to other nearby grain and in this way rust may spread within a few weeks over a wide area.

In order to explain more fully the life cycle of the stem-rust fungus, the accompanying chart (Fig. 1) is presented.

The black or winter spores of the rust on the stubble and straw cannot cause infection of other grain except thru the barberry.

Thus in our latitude the common barberry[3] plays a vital part in the life and spread of black stem rust. Years of investigation have shown that this shrub is responsible for the spread of stem rust to wheat, oats, barley and rye and about 60 different kinds of wild grasses. By destroying the barberry thruout the states where stem rust cannot overwinter, epidemics of the rust can be prevented.

How to Identify the Common Barberry

Fig. 3.—Cultivated Barberry

A—The common barberry (Berberis Vulgaris) showing the triple-pointed spines, bristle-toothed leaves and fruit clusters.

B—The Japanese barberry (Berberis thunbergii) showing the single spines, fruit and smooth leaves.

The common barberry[3] is a tall, erect shrub often growing to a height of 14 feet. It is characterized by spines along the stem and by greyish bark (Fig 2 and 3). The spines almost always are triple-pointed, altho occasionally one finds them armed with four or more points. Again they may be found with their points reduced to a single sharp thorn. The leaves are green or purple and are closely bristle - toothed around the margin. They occur in rosettes on the stems where they develop from the axils of the spines. The yellow flowers and red berries occur in clusters like those of currants. The clusters of red berries are usually very numerous and remain on the plants

[3]*Berberis Vulgaris*

thruout the winter. The roots and wood of this type of barberry plant are decidedly yellow in color.

The Japanese Barberry

The Japanese barberry[4] is a shrub of low and spreading habit, seldom exceeding five feet in height. (Fig. 3). The bark is reddish-brown. The spines occur singly on the stem, but sometimes they are two or three-pointed. The leaves are entire, thus differing from those of the common barberry. The yellow flowers and red berries are similar to those of the common barberry, but are in smaller clusters more like gooseberries and not like currants. This bush is beautiful and makes a very fine hedge. It is not at all subject to attack by black stem rust and should be planted in preference to the common barberry.

Barberries Native to Colorado

Besides the common and Japanese barberries, which have been

Fig. 4.—Native wild barberry (Berberis fendleri) on hillside near Pagosa Springs, Colorado.

introduced into Colorado, a native species [5] occures here and there in the mountains of the state. (Fig. 4). This wild barberry for some time has been thought to be susceptible to black stem rust altho no inoculation experiments previously reported have given positive results.

As this native species is prevalent in sections of Colorado not far removed from cultivated areas, tests were made of its susceptibility to stem rust under controlled conditions. Inoculations of rapidly growing shoots of this plant were made with teleutospores of stem

[4] *Berberis thunbergii*
[5] *Berberis fendleri*

rust from wild barley.[6] Within seven days from the time of inoculation profuse infection developed on the barberry leaves. The infection was so extensive as to kill many of the leaves.

Inoculations on Little Club wheat, with cluster-cup spores from the wild barberry,[5] produced abundant red-rust infection on the grain in eight days.

This test often repeated, definitely places the wild mountain barberry[5] among the susceptible species of barberries and indicates beyond doubt that this shrub may act as an alternate host for black

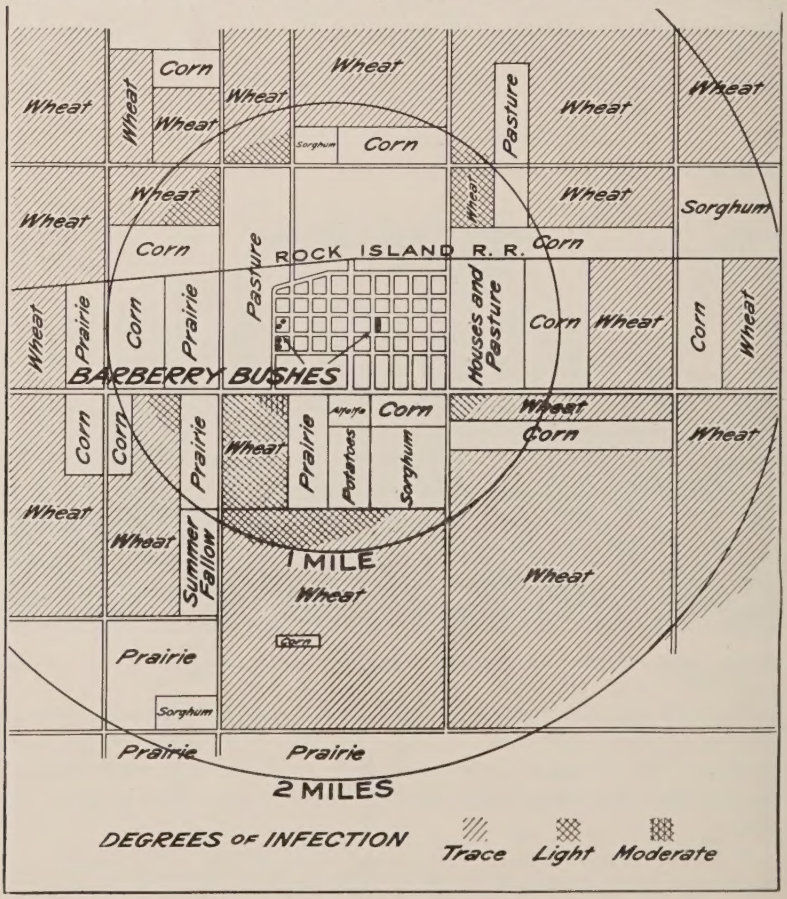

Fig. 5.—Spread of Stem Rust from Common Barberry to Grains and Grasses. Burlington, Colorado, June 26, 1922.

[5] *Berberis fenderli*
[6] *Hordeum jubatum*

stem rust.[2] This shrub should not be transplanted or sold in the wheat or grain area.

The Spread of Rust from the Common Barberry

In all cases in Colorado where the summer stage of stem rust has been found early in the spring on grains or grasses, the infection has been traced to the common barberry. The earliest appearance of rust on the barberry occurs from the middle to the last of May in Colorado, and spore discharge from the cluster cups is active from the last of May to the first week in June.

A number of excellent examples of stem-rust epidemics started by infected barberry bushes have been observed and mapped during past years in Weld, Yuma, Larimer and Kit Carson counties. A very striking occurence of rust spread was observed June 26, 1922, at Burlington, Colorado. Twelve heavily infected barberry bushes were found on three town properties. From these bushes rust had spread to the wild grasses scattered in the vacant lots about town. The rust had spread from these grasses to the grain fields in the vicinity of the town, extending to a distance of 15 miles on the north and west. The fields closest to the town were most heavily infected and the rust decreased farther away to a point beyond 15 miles where no rust could be found. Figure 5 shows in detail the spread of rust from this particular place.

Many instances similar to that described above were surveyed, not only in small towns, but on individual farms.

When bushes are scattered over a territory rust may spread from them to such an extent as to constitute an epidemic. **Even a lone barberry bush may become a great menace to the wheat in a community.** It is important, therefore, to get out all the barberries.

History of Barberry Eradication

From the many observations made on the spread of stem rust from barberries in this and other counties, it has been plainly demonstrated that the common barberry is a source of black stem rust, and that destruction of the bush will lessen or even eliminate the rust. Denmark controlled wheat rust more than 20 years ago by eradicating the common barberries.

A call for increased cereal production during the late war and our experience in the terrible rust epidemic of 1916, did much to emphasize the importance of a campaign of barberry eradication in the United States. Accordingly, the present compaign was begun in 1918. This important project has been conducted by the Office of Cereal Crops and Diseases of the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Colleges

[2] *Puccinia graminis tritici*

of Agriculture, State Departments of Agriculture and other agencies in the following states: Colorado, Illinois, Indiana, Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin and Wyoming.

An organization of the barberry eradication campaign in Colorado was effected and a preliminary survey begun in 1918. The actual eradication of the common barberry in this State was begun in 1919. In July of that year, quarantine No. 8 was issued by the State Entomologist of Colorado. This quarantine declared the common barberry bush and its horticultural varieties to be pests because they harbor the black stem rust, a disease destructive to grains and grasses.

The results of the original survey carried forward thruout the field seasons from 1919 to June 30, 1926, show that on the latter date 24,454 common barberry bushes had been found in the cities, towns and rural districts of Colorado. (Fig. 6). Of these, 23,912 have been

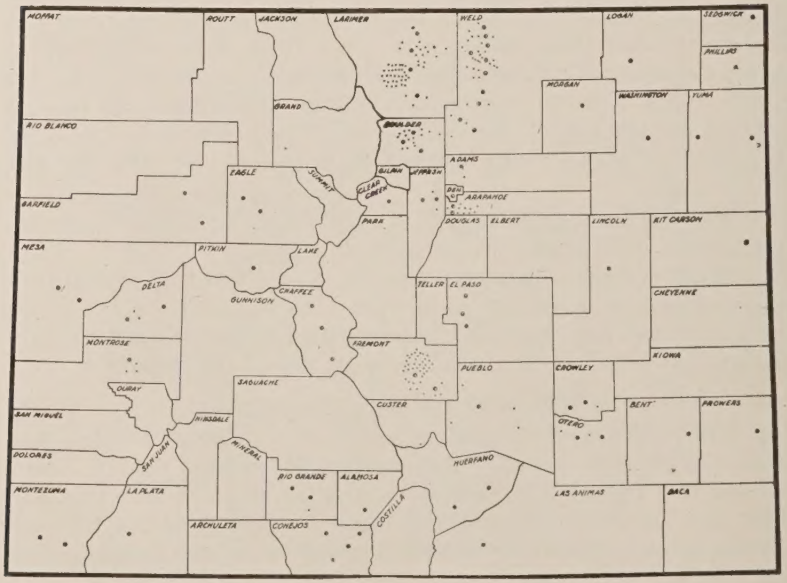

Fig. 6.—Location of barberry plantings in Colorado to June 30, 1926.
. Farms on which barberry bushes were destroyed.
o Towns in which barberry bushes were destroyed.

destroyed by digging and 538 by chemicals, making a total of 24,450 bushes destroyed. Some of these, tho apparently killed, have produced sprouts from pieces of roots left in the soil. In resurveys during the entire campaign, 6,922 such sprouting bushes have been found on 1,620 properties. Also during the entire campaign, 3,634 seedlings have been found on 99 properties. This makes a total of 35,010 bar-

berry plants, sprouting bushes and seedlings found in Colorado to June 30, 1926. Of this number 35,006 have been destroyed.

Methods of Survey for Common Barberries

In 1918 and 1919, it was thought that Colorado's common barberries were confined entirely to cities and towns. At that time a survey was made of all the towns of Colorado. All the barberries found in them were dug. Later it was found that barberries had been planted on farms and had escaped from cultivation thru distribution of the barberry seeds by birds and irrigation waters. It then became necessary to make a survey of rural properties. In this survey, every farm and town property in a county was visited and all bushes found were either dug or salted.

The fact that the seeds from the planted bushes are carried by birds, would naturally lead one to look for seedlings and escaped bushes in woodlets, orchards, and groves, and sometimes along streams and irrigation ditches several miles from the original plantings. In order to get all such barberries, the original survey has been followed by resurveys to recheck all properties and destroy any sprouts or escaped bushes. In this way, many areas have been found where common barberries have escaped from cultivation and spread for several miles. Such areas were found near Loveland, Wolhurst, Ft. Collins, Littleton, Greeley, Canon City and Montrose. On many of the farms near these towns seedlings and escaped bushes were found. It is necessary to resurvey areas of this nature many times for seedlings, sprouts and escaped bushes. In Figure 7 is shown a clump of escaped barberries growing along a fence.

Fig. 7.—Escaped common barberry near a fence. Such bushes grow from seeds dropped by birds.

To check up on the efficiency of the original survey and subsequent resurveys, several counties have been given a second complete survey. This survey consists of a second and very thoro inspection of all the properties

in the county. In spite of the fact that a county is given an original survey and resurvey, there is a great danger that the field scouts will miss some bushes. In 1926 two counties and a half of another were given a second survey. In this survey, 130 bushels were found. This result points to the necessity of careful and thoro inspection of each property before it can be reasonably certain that it is free from the common barberry. This is especially true of regions where old bushes have stood and seedlings have developed in groves or along ditch banks.

Methods of Eradicating Barberries in Colorado

The common barberry is a very hardy shrub and difficult to kill. At the beginning of the campaign, all bushels found were dug. Later, resurveys showed that many of the bushes removed by digging were being replaced by sprouts arising from root fragments. Unless

Fig. 8.—Escaped common barberries salted with seventy-five pounds of salt, sufficient to completely kill the whole clump.

a very careful job of digging is done, sprouts will spring up. A piece of root less than about the size of a lead pencil, when allowed to stay in the ground, will produce a new barberry plant and thus make more difficult the problem of eradication.

Experiments conducted for the purpose of finding some chemical which will kill the barberry bush have proved crushed rock salt and kerosene to be the most effective and satisfactory of the many that were tried. Both are cheap and easily obtained.

Whenever possible, therefore, it is best to use chemicals to replace the digging method. It has been found that 10 pounds of rock salt applied to the crown will kill a bush one foot in diameter at the

ground line. When rock salt is used it is well to pour on a bucket or two of water after applying the salt. If kerosene is used, one gallon applied to the base of the plant will kill a bush of the above size. For smaller or larger bushes, proportionate amounts should be used. After the chemical is applied, only a short time is required before the danger of sprouting is eliminated. When other kinds of trees or shrubbery are growing within three or four feet of the bush to be destroyed, chemicals should not be applied because of the danger of killing the other plants. In Fig. 8, is shown a group of barberry plants treated with salt in the manner described above.

In using salt, there is some danger to livestock, especially poultry and hogs. To prevent any possible harm to livestock, the salt should be covered with dirt, stones or boards.

The question sometimes arises as to how long a time will be required before other shrubbery can safely be planted in the treated soil. From observations made in the irrigated section, where leaching takes place rapidly, it usually is safe to plant new shrubbery within two years. In the dry-land area more time is required. In Figure 8 is shown a group of barberry plants treated with salt in the manner described above.

Cooperation

The effectiveness of the barberry-eradication campaign depends not only on the quality of the survey done by the agents of the United States Department of Agriculture, but also on the cooperation of the residents and property owners of each community in Colorado. Every property owner should become acquainted with the common barberry bush and aid in its destruction. When in doubt as to the identity of the bush, a specimen should be sent to the Botany Department, Colorado Agricultural College, Fort Collins, Colorado, for identification.

Overwintering of the Red Rust in Colorado

In the northern states the red-rust stage of stem rust normally perishes with the green leaves and stems of the grain or is displaced by the black rust stage. In this form it lives over winter and, as previously described, these black spores germinate and infect only common barberries.

In some of the southern states, however, it is generally known that the rust does live over winter in the red-rust form. The question arises whether or not the same thing occurs here. Does the rust live over winter in Colorado in the red-rust stage, later to start local epidemics independent of the barberry.

During five winters, red-rust spores have been taken from grains and various grasses in a number of localities thruout the state to

determine if such spores remained viable under the conditions of Colorado winters. During these years various types of weather were experienced. The spores were collected from both low and high altitudes and their ability to grow was tested every month during the fall and winter. In the spring, the spores were gathered and tested for germinability every week or two weeks. The different plots from which collections were made and the grasses or grains bearing the spores, together with their germination records, are shown in the accompanying table. The results of these tests indicate that the summer spores of black stem rust [2] have been found alive in the field in northern Colorado thruout the winter and until May 28, altho the ability to germinate had decreased to two percent by that date. Tests made during the years 1921 to 1925 show that these spores survive when enclosed within the leaf sheath of the dead stalks and are capable of infecting Little Club wheat under controlled conditions in the greenhouse. The spores do not survive under the dry conditions of the wheat lands, but only on wild barley [6] near the edge of lakes and sloughs.

Notwithstanding the infecting ability of these spores and the fact that fresh green plants are abundant for reinfection several weeks before May 28, no natural infection from this source has ever been found. The spores are closely enclosed within the leaf sheath of dead plants and apparently are not scattered.

Final dates on which Red Rust Spores of *Puccinia graminis tritici* on grains and grasses were found not germinating under field conditions.

Date	Location	Grass or Grain
February 14	Fort Collins	Wild Barley
February 14	Fort Collins	Wheat Grass
April 12	Fort Collins	Wild Barley
April 14	Fort Collins	Wild Barley
*May 28	Wellington	Wild Barley
April 23	Fort Collins	Wheat Grass
April 23	Fort Collins (mountains)	Wheat Grass
April 23	Fort Collins	Wild Barley
April 23	Fort Collins	Wild Barley
Dec. 20	Fort Collins	Wheat
April 23	Fort Collins	Wheat Grass
Jan. 10	Akron	Wheat Grass
February 15	Cheraw	Wild Barley

Note: In the above table wild barley—*Hordeum jubatum.*
wheat grass—*Agropyron sp.*
Stem rust on timothy overwinters in Colorado and was used for a check.
*Still germinating at this date.

Migration of Rust Into Colorado

Since the beginning of eradication of barberries in Colorado, it has been a question as to what may be the final effect of the destruction of the bush on the control of blackstem rust in the state. The section from the mountains to the state line on the east grows annually about 1,150,000 acres of wheat. At one time this area was well supplied with planted and escaped barberry bushes and suffered repeated losses from stem rust. Since 1919 this territory has been given

[6] *Hordeum jubatum*
[2] *Puccinia graminis tritici*

both the original survey and resurvey. The destruction of 35,006 barberry plants, sprouting bushes and seedlings in this wheat-producing section has done much to rid the state of at least one very important source of initial infection.

The behavior of the rust over so large an area, following this numerical decrease of the barberry, is of particular interest as the instance is more or less unique.

During the five years observation in Colorado, it has been found that barberries may become infected as early as May 8 and that rust may spread from them by the first of June. Early appearance of stem rust in the state always has been traced to barberries. In many cases initial infection has been traced 6 to 10 miles to individual bushes. Since the reduction of the number of barberries in the dryland counties east of the mountains, such stem-rust infection as has occurred has developed late and has not been directly traceable to barberries. Apparently it has come into the state from the east and south altho it may have come from undiscovered barberries.

It is known that the summer or re-spore stage of stem rust can live thru the winter in the far Southern States. In these states the barberry is not a necessary factor in stem-rust propagation. The red stage of the rust may spread from this source and be carried north and west by the wind.

During the last four years, observations made along the eastern border of the state show the first appearance of rust to be from June 23 to June 25. Fields were examined carefully and search made for the first trace of rust. At this date, rust could be found only from 5 to 10 miles west of the state line. In the dryland section to the west, no rust was present. The rust spread indicated a definite migration from east to west which could easily be followed by surveys.

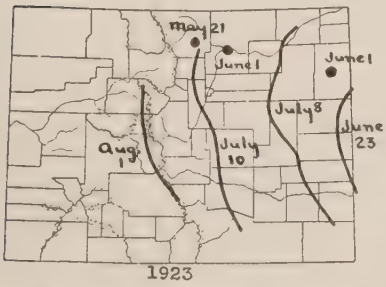

Fig. 9.—Stem rust advance in Colorado in 1923. The dots (.) show location of infected barberry sprouts. The successive parallel lines show the limit of westward advance of stem rust on date named, as determined by survey.

In figure 9 is shown a state map representing the spread of stem rust from the eastern state line. In this map the three black spots represent the location of known infected barberry sprouts. Infection of barberries was noted at these locations on May 21, and rust was spreading from these bushes during the first part of June. No other rust was found in the state other than from these localities

until June 23, when rust was found on the Colorado-Kansas border near Burlington. By July 8 the rust could be found as far westward as the line on the map indicated by that date.

By July 10 rust could be found still further west and by August 1 it had spread into the mountain valleys. A similar case of rust movement across the state in 1924 is shown in Figure 10. The migration in 1924 was virtually identical with that observed in 1923. In 1925 conditions again were the same, tho stem rust appeared and advanced a few days earlier.

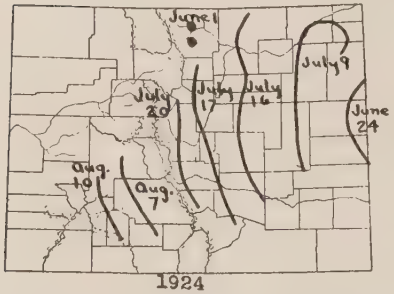

Fig. 10.—Stem rust advance in Colorado in 1924. The dots (.) show locations of infected barberry sprouts. The successive parallel lines show the limit of westward advance of stem rust on date named, as determined by survey.

The careful surveys across the state, on which these data are based, showed rust as indicated in the accompanying maps. Furthermore, after the rust had started into the state it was most abundant along the eastern border. Surveys carried across the state westward from the Colorado-Kansas border showed the rust in ever-diminishing percentages.

Stem-rust infection in the irrigated sections of Colorado, some 250 miles west of the eastern border, occurs 12 to 17 days later than the first appearance in the eastern part of the state, in the absence of local infection from barberries.

Where the barberry has been eradicated in the wheat area of eastern Colorado, the source of initial inoculum has been destroyed. This has not prevented rust completely, but has definitely slowed it up. Where rust previously spread from the barberry the first of June, starting infection on grain at that time, it now enters the state 2 to 3 weeks later. In normal years this is late enough to allow the grain to mature before the rust can cause serious damage.

Recommendation for Control of Stem Rust

Eradicate the common barberry. This bush is responsible for the early spread of rust, especially in local areas. It is important that all the bushes be destroyed and no new ones planted. We are approaching complete destruction of the barberry in the dryland area of the state, but all bushes must be destroyed. The results of state surveys are very encouraging and begin to show that we may expect freedom from serious rust damage when all barberries are destroyed. The barberry sprouts so readily and is so easily dissemi-

nated by birds that unless the destruction is thoro now, our wheat, again will be in danger 20 or 30 years hence.

Everyone should know the barberry bush and be on the lookout for stray plants along streams and ditches. If such are found, they should be reported to the Botanical Department, State Agricultural College, Fort Collins, Colorado.

Summary

Black stem rust normally lives over winter in the black-rust stage on wheat, straw and stubble or on wild grasses. Thence it finds its way to the common barberry but cannot reinfect grain. The common barberry bush, therefore, is the chief source of initial stem-rust inoculum in Colorado. It can be identified by its three or more pointed spines, bristle-toothed leaves and current-like clusters of red berries.

The native barberry, found in the mountains, resembles the common barberry and also can spread rust. It should not be transplanted from its native habitat to places near grain fields.

The Japanese barberry has smooth-edged leaves, single spines and is immune from rust. It therefore can safely be planted in place of the common variety, and is quite as attractive as an ornamental shrub.

Many cases of spread of stem rust from common barberry have been found in Colorado. The spread of rust from the barberry to wild grasses or grains often extends for miles. A single barberry bush may be the source of a local rust epidemic. Barberries scattered thru adjoining areas may early start an infection of rust that may develop into a general epidemic.

The barberry being recognized as such a menace to the wheat crop eradication of the bush was begun in Colorado in 1919. Quarantine No. 8 was issued by the State Entomologist of Colorado. To June 30, 1926, a total of 35,006 common barberries, sprouting bushes and seedlings have been destroyed in Colorado.

Barberries are found by surveying all town and country properties in the state. As birds carry the seeds, bushes are found along ditches, in groves and along fence rows. In most obscure places, an exhaustive search of properties is necessary to find all bushes. In most counties three surveys are made so that no bushes are overlooked.

The barberry bush is very hardy and unless a thoro job of digging is done, sprouts will appear. To assure the best eradication, apply 10 pounds of rock salt to the crown of a bush of about a foot in diameter. If there is danger of chickens or stock eating the salt, cover with boards or dirt.

Studies on the overwintering of stem-rust urediniospores have been conducted in Colorado during five years. These red-rust spores on wild barley have been found to germinate until late spring, but no natural infection or spread has ever been found which was traceable to this source.

With the eradication of the common barberry, the early spread of rust is stopped. Stem rust comes in, however, from states to the east and southeast, appearing from one to two weeks later than when initiated by the barberry. In general, this delay affords the crop opportunity to mature before the rust has reached its most active and maximum development.

Destroy the common barberry. Watch for escaped bushes along fences and ditches. If in doubt about the plant, send a specimen for identification to the Department of Botany, State Agricultural College, Fort Collins, Colorado, or the United States Department of Agriculture, Washington, D. C.

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